

Applicant hereby elects to prosecute the claims to the apparatus and has deleted the method claims without prejudice to filing a divisional application for the method.

The amendments to the disclosure are primarily to correct minor typographical errors. The additions to page 7 line 24 and page 8 line 30 are simply to state the obvious and do not add any new matter, nor do any of the other changes add new matter.

By this amendment a claim 1 has been revised to more clearly define the invention and the dependent claims have been revised significantly and presented as new claims 21 to 45. The reference to the seal has been deleted from claim 1 and added in dependent claim 26, but the other limitations have been retained and in some areas made more specific. It is submitted that the inclusion of the seal in the broadest claim is not essential to distinguish the invention from the prior art

It is believed this application is now in condition for Allowance and such action is respectfully requested.

Respectfully submitted


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Version with markings to show the changes made

In the Title

The title has been amended as follows

Liquid-Solids [Circulation] Circulating Fluidized Bed

In the Disclosure

The paragraph beginning on page 1 line 6 has been amended as follows

Fluidized beds have been used for a number of different applications such as gas-liquid, [gas liquid solid, solid] ~~gas-liquid-solid~~ contactors and to carry out a variety of different processes such as chemical [reactors] ~~reactions~~.

The paragraph beginning on page 1 line 28 has been amended as follows

Porter and Robert [[], US patent 3,879,287, "Continuous ion exchange process and apparatus" (1975) relates to an apparatus for continuous ion exchange. However, the process described is a semi-continuous process as the recommended eluting means is a batch wise conventional ~~fixed~~ bed ion exchange process.

The paragraph beginning on page 2 line 17 has been amended as follows

It is also an object of the present invention to provide a process for continuous recovery of the ions of interest for example [contamininants] ~~contaminants~~ in liquid streams or value added products from waste streams using a Liquid-Solids [Circulation] ~~Circulating~~ Fluidized Bed (LSCFB) ion exchange system.

The paragraph beginning on page 2 line 21 has been amended as follows

Broadly the present invention relates to a fluidized bed system comprising a first fluidized bed, ~~said fluidized bed being a conventional fluidized bed~~, means to feed solids into said first fluidized bed adjacent to a first end of said first fluidized bed and means to feed a first fluid into said first fluidized bed adjacent to a second end of said first fluidized bed, said second end being remote from said first end so that said solids and said first fluid flow in counter current, a second fluidized bed, said second fluidized bed being an entraining fluidized bed wherein a

means for introducing solids and a means for introducing a second fluid into said second bed are both adjacent to the one end of said second fluidized bed so that said solids and said second fluid introduced into said second bed flow concurrently through said second bed from said one end toward another end of said second fluidized bed remote from said one end, first means connecting said first fluidized bed to said second fluidized bed adjacent to said second end of said first fluidized bed and said one end of said second fluidized bed and said first means connecting including said means to feed solids into said second fluidized bed, and second means connecting said first and said second fluidized beds adjacent said first end of said first bed and said other end of said second fluidized bed, [said first means connecting being adapted to form a hydraulic seal between said first and second fluidized beds] and said second means connecting including said means to feed solids into said first fluidized bed. Preferably said first and said second means connecting being adapted to form a hydraulic seal between said first and second fluidized beds

The paragraph beginning on page 3 line 12 has been amended as follows

Preferably said first means connecting said first and said second fluidized beds includes a second washer for washing solids adjacent to said second end of said first fluidized bed before they are introduced into said second fluidized bed.

The paragraph beginning on page 3 line 15 has been amended as follows

Preferably said first fluidized bed is an absorber for separating ionic products of interest and said second fluidized bed is a desorber for desorption of ionic products and said solids are ion exchange particles [said second means for connecting including said means to feed solids to said first fluidized bed]. That is, the said liquid-solid circulating fluidized bed system can preferably be used to recover ionic products of interest by passing ion exchange particles in countercurrent flow with a feed stream of a first fluid through a first fluidized bed for adsorption of ionic products of interest from said feed stream of said first fluid, transferring said particles with adsorbed ionic products of interest from said first fluidized bed to a second fluidized bed and passing said ion exchange particles with adsorbed ionic products in cocurrent flow with an extract buffer of a second fluid through said second fluidized bed for desorption of said adsorbed ionic products of interest, separating said second fluid containing said ionic

~~products of interest desorbed from said ion exchange particles by said second fluid to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said first fluidized bed to flow in countercurrent with said first fluid.~~

The paragraph beginning on page 3 line 19 has been amended as follows

[Broadly the present invention also relates to a method of recovering ionic products of interest comprising passing ion exchange particles in countercurrent flow with a feed stream of a first fluid through a first fluidized bed for adsorption of ionic products of interest from said feed stream of said first fluid, transferring said particles with adsorbed ionic products of interest from said first fluidized bed to a second fluidized bed and passing said ion exchange particles with adsorbed ionic products in co current flow with an extract buffer of a second fluid through said second fluidized bed for desorption of said adsorbed ionic products of interest, separating said second fluid containing said ionic products of interest desorbed from said ion exchange particles by said second fluid to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said first fluidized bed to flow in countercurrent with said first fluid.]

The paragraph beginning on page 5 line 23 has been amended as follows

-In the LSCFB ion exchange system of the present invention, the solids circulation rate is controlled by a butterfly valve schematically indicated at 70 located on the bottom solids return pipe 42. The mechanical valve is preferred over a hydraulic valve due to the low density of the most ion exchange particles, which makes the operation of the hydraulic valve more difficult. An additional advantage of using the mechanical valve in this situation is that it enhances the pressure drop across the solids return pipe 42 and therefore makes the system more stable. The auxiliary liquid stream 62 may be used to provide additional control of the solids circulation rate.-

The paragraph beginning on page 5 line 31 has been amended as follows

The feed liquor 20 as above described enters at the bottom of the bed 10, travels in countercurrent to the particles 18 through the bed 12 and [leave] leaves at the top of the bed as indicated at 44. The fluid exiting from 44 is discarded as waste or as a purified stream in

the case of contaminant removal.

The paragraph beginning on page 6 line 3 has been amended as follows

The second fluidizing fluid (extract buffer) 28 and the particles 18 from line 42 travel in [co-current] co-current fashion upward through the bed 12 and are regenerated and then enter the transfer system 16 which includes a separator such as the fluid vortex type separator 46 having a fluid outlet 48 through which the second fluidizing fluid 28 is removed and a solids outlet through a washing stage 50 at the bottom. This fluid exiting from outlet 48 contains the ions of interest and may be subjected to further downstream processing or membrane treatment to concentrate the ions of interest. Washing fluid is injected via nozzle 52 at the bottom of the washing stage 50 and flow upward in countercurrent with the downcoming solids (regenerated solid particles) 18 and the so washed particles 18 enter the inlet tube delivering the regenerated particles 18 into the top of the bed 10. The washing fluid dilutes the extract buffer and exits from the outlet 48.

The paragraph beginning on page 6 line 16 has been amended as follows

In the process of ion exchange, the feed liquor 20 is introduced via inlet 22 into the bottom (second) end of the first fluidized bed 10 (downcomer 10) and the regenerated particles 18 from the bed 12 are introduced via line 17 adjacent to the first or the top of the first fluidized bed 10, i.e. the feed 20 and regenerated beads are introduced at opposite ends of the first fluidized bed 10.

The following paragraph has been added following the paragraph ending on page 7 line 24

Although the invention has been illustrated with the feed liquor flowing upwards in countercurrent with the particles in the first fluidized bed and the extract buffer flowing upwards in cocurrent with the particles in the second fluidized bed, it will be clear to those skilled in the art that the two fluidizing fluids can be switched with the feed liquor flowing upwards in cocurrent with the particles in the second fluidized bed and the extract buffer flowing upwards in countercurrent with the particles in the first fluidized bed.

The paragraph beginning on page 8 line 12 has been amended as follows

In the liquid solids [circulation] circulating fluidized bed (LSCFB), diagrammed in Figure 1, the adsorption in the first fluidized bed or downcomer 10 and the desorption in the second fluidized bed or second fluidized bed 12 can be carried out in a continuous mode with the ion exchange particles circulated continuously between the two columns. The ion exchange particles 18 employed in this system should have reasonably large adsorption capacity to the target or desired ions and the density of the ion exchange particles 18 in the swollen state should be larger than that of the feed liquor. As the first fluidized bed 10 is maintained in the conventional fluidization regime, the bed voidage could be adjusted to allow the passage of the particulates in an unclarified feed by controlling the superficial liquid velocity in the first fluidized bed. In other words, this system can be used to purify the target ions directly from an unclarified whole broth so that the costly pre-clarification process is eliminated.

The following paragraph has been added following the paragraph ending on page 8 line 30

Although the above description uses the first fluidized bed for adsorption and the second fluidized bed for desorption, it will be understood by those skilled in the art that one can also use the second fluidized bed for adsorption and the first fluidized bed for desorption.

The paragraph beginning on page 8 line 32 has been amended as follows

In an arrangement as shown in Figure 1, the second fluidized bed 12 is an acrylic column of I.D. 38.1 mm and 3 m in height. The distributor of the second fluidized bed 12 divides the incoming stream of extracting buffer [is divided] into two substreams: the primary 60 and the auxiliary 62 streams. The primary stream 60 is introduced through a stainless steel pipe (I.D. 11 mm) (nozzle 30). It projects 36 mm into the second fluidized bed column 12. Since the liquid velocity in the second fluidized bed is maintained in a range higher than the terminal velocity of the ion exchange particles, the high liquid velocity enhances the contact efficiency and also the mass transfer rate between the liquid and the particles.

The paragraph beginning on page 10 line 5 has been amended as follows

Potential applications of the invention that the invention is believed to be suitable for include but are not limited to:

In the claims

Claim 1 has been amended as follows

A liquid-solid circulating fluidized bed system comprising a first liquid fluidized bed, ~~said first liquid fluidized bed being a conventional liquid fluidized bed~~, means to feed solids into said first fluidized bed adjacent to a first end of said first fluidized bed and means to feed a first fluid into said first fluidized bed adjacent to a second end of said first fluidized bed, said second end being remote from said first end so that said solids and said first fluid flow in counter current, a second liquid fluidized bed, said second liquid fluidized bed being ~~a riser and~~ [an] entraining liquid fluidized bed wherein a means for introducing solids and a means for introducing a second fluid into said second bed are both adjacent to one end of said second fluidized bed so that said solids and said second fluid introduced into said second bed flow concurrently through said second bed from said one end toward another end of said second fluidized bed remote from said one end, first means connecting said first fluidized bed to said second fluidized bed adjacent to said second end of said first fluidized bed and said one end of said second fluidized bed, ~~said first connecting means includes means to feed said solids into said second fluidized bed~~, [and] second means connecting said first and said second fluidized beds adjacent said first end of said first bed and said other end of said second fluidized bed, [said first means connecting being adapted to form a hydraulic seal between said first and second fluidized beds and] said second means connecting includes said means to feed solids into said first fluidized bed.

Claims 2 to 20 have been cancelled

New claims 21 to 45 have been added as follows

- 21 ~~A liquid-solid circulating fluidized bed system as defined in claim 1 wherein said first and second liquid fluidized beds are substantially vertical columns.~~
- 22 ~~A liquid-solid circulating fluidized bed system as defined in claim 21 wherein said first end of said first fluidized bed is the top end, said second end of said first fluidized bed is the bottom end, said one end of the second fluidized beds is the bottom end and said other end of said second fluidized bed is the top end.~~
- 23 ~~A liquid-solid circulating fluidized bed system as defined in claim 22 wherein said first fluid essentially flows upwards and said solids essentially flow downwards to form a~~

counter current flow in said first fluidized bed, and wherein said second fluid and solids both essentially flow upwards concurrently in the second fluidized beds.

- 24 A liquid-solid circulating fluidized bed system as defined in claim 23 wherein second means connecting said first and said second liquid fluidized beds includes a washer for washing said solids before they are fed into said first end of said first fluidized bed.
- 25 A liquid-solid circulating fluidized bed system as defined in claim 24 wherein said second means connecting said first and said second liquid fluidized beds further includes a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids.
- 26 A liquid-solid circulating fluidized bed system as defined in claim 24 wherein said second means connecting said first and said second liquid fluidized beds further includes a hydraulic seal between said first and second fluidized beds.
- 27 A liquid-solid circulating fluidized bed system as defined in claim 23 wherein said first means connecting said first and said second liquid fluidized beds includes a second washer for washing solids adjacent to said second end of said first fluidized before they are introduced into said second fluidized bed.
- 28 A liquid-solid circulating fluidized bed system as defined in claim 27 wherein said first means connecting said first and said second liquid fluidized beds further includes a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids.
- 29 A liquid-solid circulating fluidized bed system as defined in claim 27 wherein said first means connecting said first and said second liquid fluidized beds further includes a hydraulic seal between said first and second fluidized beds.
- 30 A liquid-solid circulating fluidized bed system as defined in claim 1 wherein the recover of ionic products of interest is realized by passing ion exchange particles as the said solids in countercurrent flow with a feed fluid stream that contains said ionic products of interest as said first fluid through the said first liquid fluidized bed for adsorption of said ionic products from said feed stream, transferring said ion exchange particles with said adsorbed ionic products of interest from said first fluidized bed to said second fluidized bed, passing said ion exchange particles with absorbed ionic products in concurrent flow with an extract buffer solution as said second fluid through said second liquid fluidized

bed for desorption of said adsorbed ionic products of interest, separating said extract buffer solution containing said ionic products of interest desorbed from said ion exchange particles to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said first fluidized bed to flow in countercurrent with said first fluid.

31 A liquid-solid circulating fluidized bed system as defined in claim 1 wherein the recover of ionic products of interest is realized by passing ion exchange particles as the said solids in concurrent flow with a feed fluid stream that contains said ionic products of interest as said second fluid through the said second liquid fluidized bed for adsorption of said ionic products from said feed stream, transferring said ion exchange particles with said adsorbed ionic products of interest from said second fluidized bed to said first liquid fluidized bed, passing said ion exchange particles with absorbed ionic products in countercurrent flow with an extract buffer solution as said first fluid through said first fluidized bed for desorption of said adsorbed ionic products of interest, separating said extract buffer solution containing said ionic products of interest desorbed from said ion exchange particles to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said second fluidized bed to flow in concurrent with said second fluid.

32 A liquid-solid circulating fluidized bed system as defined in claim 23 wherein the recover of ionic products of interest is realized by passing ion exchange particles as the said solids in countercurrent flow with a feed fluid stream that contains said ionic products of interest as said first fluid through the said first liquid fluidized bed for adsorption of said ionic products from said feed stream, transferring said ion exchange particles with said adsorbed ionic products of interest from said first fluidized bed to said second liquid fluidized bed, passing said ion exchange particles with absorbed ionic products in concurrent flow with an extract buffer solution as said second fluid through said second fluidized bed for desorption of said adsorbed ionic products of interest, separating said extract buffer solution containing said ionic products of interest desorbed from said ion exchange particles to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said first fluidized bed to flow in countercurrent with said first fluid.

- 33 A liquid-solid circulating fluidized bed system as defined in claim 23 wherein the recover of ionic products of interest is realized by passing ion exchange particles as the said solids in concurrent flow with a feed fluid stream that contains said ionic products of interest as said second fluid through the said second liquid fluidized bed for adsorption of said ionic products from said feed stream, transferring said ion exchange particles with said adsorbed ionic products of interest from said second fluidized bed to said first liquid fluidized bed, passing said ion exchange particles with absorbed ionic products in countercurrent flow with an extract buffer solution as said first fluid through said first fluidized bed for desorption of said adsorbed ionic products of interest, separating said extract buffer solution containing said ionic products of interest desorbed from said ion exchange particles to provide regenerated ion exchange particles and returning said regenerated ion exchanged particles into said second fluidized bed to flow in concurrent with said second fluid.
- 34 A liquid-solid circulating fluidized bed system as defined in claim 32 wherein second means connecting said first and said second liquid fluidized beds includes a washer for washing said solids before they are fed into said first end of said first fluidized bed, a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids, and a hydraulic seal between said first and second fluidized beds.
- 35 A liquid-solid circulating fluidized bed system as defined in claim 33 wherein second means connecting said first and said second liquid fluidized beds includes a washer for washing said solids before they are fed into said first end of said first fluidized bed, a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids, and a hydraulic seal between said first and second fluidized beds.
- 36 A liquid-solid circulating fluidized bed system as defined in claim 32 wherein said first means connecting said first and said liquid second fluidized beds includes a second washer for washing solids adjacent to said second end of said first fluidized before they are introduced into said second fluidized bed, a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids, and a hydraulic seal between said first and second fluidized beds.

- 37 A liquid-solid circulating fluidized bed system as defined in claim 33 wherein said first means connecting said first and said second liquid fluidized beds includes a second washer for washing solids adjacent to said second end of said first fluidized before they are introduced into said second fluidized bed, a separator means for separating solids from fluid and exhausting such separated fluid to provide separated solids, and a hydraulic seal between said first and second fluidized beds.
- 38 A liquid-solid circulating fluidized bed system as defined in claim 32 wherein said ionic product is a protein and said first fluid is a fermentation broth.
- 39 A liquid-solid circulating fluidized bed system as defined in claim 33 wherein said ionic product is a protein and said first fluid is a fermentation broth.
- 40 A liquid-solid circulating fluidized bed system as defined in claim 32 wherein said ionic product is a metal and said first fluid is sea water.
- 41 A liquid-solid circulating fluidized bed system as defined in claim 33 wherein said ionic product is a metal and said first fluid is sea water.
- 42 A liquid-solid circulating fluidized bed system as defined in claim 32 wherein said ionic product is an enzyme and said first fluid is dextrose syrup.
- 43 A liquid-solid circulating fluidized bed system as defined in claim 33 wherein said ionic product is an enzyme and said first fluid is dextrose syrup.
- 44 A liquid-solid circulating fluidized bed system as defined in claim 1 wherein said first liquid fluidized bed is an absorber for separating ionic products of interest, said second liquid fluidized bed is a desorber for desorption of said ionic products, said solids are ion exchange particles, said first fluid is a feed fluid stream that contains said ionic products of interest, and said second fluid is an extract buffer solution that is suitable for desorption of said ionic products from said ion exchange particles.
- 45 A liquid-solid circulating fluidized bed system as defined in claim 1 wherein said first liquid fluidized bed is a desorber for desorption of ionic products, said second liquid fluidized bed is an absorber for separating ionic products of interest, said solids are ion exchange particles, said second fluid is a feed fluid stream that contains said ionic products of interest, and said first fluid is an extract buffer solution that is suitable for desorption of said ionic products from said ion exchange particles.